Black Box for Machine Tools; Based on Open CNC Architecture Control Systems

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***Abstract*—Most computer numerical control (CNC) systems are closed for users. Engineers typically can only program the machine, nothing more. it cannot be freely modified by the user. The introduction of open architecture philosophy propitiated the evolution of a new generation of numeric controllers. This brought the conventional CNC technology to the standard PC microcomputer. As a consequence, the characteristics of the CNC (positioning) and the micro computer (easy of programming, system configuration, network communication etc) are combined. There are also a number of commercially available OAC (Open Architecture controllers) (e.g. MDSI, Fanuc, Okuma, Siemens). There are also a number of efforts at developing OAC standards [1-4]. This paper uses Siemens [5] OAC to build the unique BlackBox for machine tool industry. This new technology in machine tool industry helps us in understanding the cause of crash or malfunctioning of machine or machine health by means of debugging the critical machine data such as Spindle Speed, Axis positions, Feed rates, Type of Tool used etc which are facilitated by this application just before the crash and same can be accessed remotely via Internet/ Ethernet. This application is successfully intergraded and tested with actual Machine.**

***Index Terms*—CNC, OAC, Machine Tool, BlackBox, HMI, PLC**

I. Introduction

Over the last 50 years there have been many developments in CNC manufacturing. These advances make today's CNC technology completely unrecognizable from their early NC ancestors. The need for a new and vendor neutral open CNC architecture was emerging at many places around the world. One of the most important works was done from 1992 within the frame of the European project named OSAC. Similar efforts are going on in Japan named OSEC under the IROFA Consortium and in the U.S. within the OMAC projects where many earlier American research results were collected.

To meet the requirements of these new machines, controllers have evolved from the early memory less controllers to modern open-architecture PC based CNCs [6-7]. In combination with these advances, programming methods have progressed to take advantage of the new processes and controller capabilities. Making advantage of OAC, concept of BlackBox is also implemented for Machine Tool Industry as a core application by means of high-level language platform tools interfaced with OAC in PC Environment. Presently BlackBox is actively used in Aircraft and Automobile industry.

A. BlackBox in Aircraft's Industry

"Black Box"[8] the aircraft's flight data recorder (FDR) and cockpit voice recorder (CVR) i.e. recording the flight crew's conversation on an airplane and of protecting that recording in the event of a crash or fire. The purpose of the Black Box was to help identify the reasons for a plane crash. Airplanes are equipped with sensors that gather data. There are sensors that detect acceleration, airspeed, altitude, flap settings, outside temperature, cabin temperature and pressure, engine performance and more. Magnetic-tape recorders can track about 100 parameters, while solid-state recorders can track more than 700 in larger aircraft. Data from both the CVR and FDR is stored on stacked memory boards inside the crash-survivable memory unit (CSMU). The memory boards have enough digital storage space to accommodate two hours of audio data for CVRs and 25 hours of flight data for FDRs. The Black Box was invented in 1953 and in production by 1957. The first ones were painted bright red or orange to make them easier to find after a crash.

B. BlackBox in Aircraft's Industry

Open, Modular Architecture controllers are also required in automotive industry [9]. In Automobile, BlackBox or Event Data Recorder (EDR)[10] module is a part of the air bag sensing system, stores information in the few seconds before a car sensor identifies a crash and fires the air bags. EDR can collect the crash data from the air bag SDM (Sensing and diagnostic module) such as speed, whether the seatbelts are fastened, and whether the driver hit the brakes before a collision. After a collision, the black box contains a record of what was happening in the last seconds before the impact. Data is permanently written on the EEPROM chip inside the airbag SDM module. Packed in a small unbreakable, shock and water proof container.

Air bag SDMs do not look at vehicle speed to determine an air bag deployment command. The airbag SDM looks for a change in acceleration on the vehicle 'X' axis to determine deployment criteria. So technically, car could be stopped or moving very slowly, be in an accident event, and deploy the air bags. A sensor mounted on the front of the vehicle supplies an input signal to the SDM. Almost all vehicles sold in North America since 1997 are collecting vehicle crash data. These include Toyota, Mercedes Benz, and Mitsubishi

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vehicles to name a few. Currently, only GM, Ford, and Chrysler have released the crash data.

II. Open CNC Architecture for Machine Tool

A. Specification of an Open Architecture System

An Open Architecture Controller should be flexible in hardware as it is in software for all control levels (Wright et al., 1996) [11]. An Open Architecture Controller must be standard to allow hardware and software development by any engineer or technician, and its integration with other controllers, cell control systems and high level planning systems (Schofield, 1996) [12].

The machine tool open controller should permit the integration of independent application program modules, control algorithms, sensor and computer hardware developed by different manufactures (Pritschow et al., 1993)[13]. An Open System allows to program in several platforms that interact with other application systems. Some specifications of an open architecture system are (Miles, 1998) (Oshiro, 1998) [14]

- Interaction: due to communication of standard data semantics;
- Interoperability: same component function by different manufacturer;
- Portability: the easy with which application software can be transferred from one environment to another.
- Scalability: system ability to increase or to decrease according to the demand.

B. Benefits of the open architecture controller

1)The use of the C + + programming in the design of the control software. Software routines can configure and implement new functions to increase the machine tool performance.
2)The application possibility of algorithm development of adaptable control for new applications, which uses force sensor, vibration sensor, acoustic sensor, etc.
3) The algorithm execution of special servo-control, increasing the machine tool precision.
4) The use of the same operator interface for different machines, simplifying user's training and reducing the costs.

III. System components of blackbox of machine tool

A. Open Architecture Controller

A commercially available Open Architecture Controller (OAC) purchased from SIEMENS [5] as the foundation of our system. The selection of the SIEMENS control was based on the following factors:
1) We wanted a Windows PC based controller that would both control the CNC and run this applications simultaneously with no adverse effects on the machining process.
2) The system must have the ability to obtain position information, i.e. x, y, z, sp1, sp2 etc in real time, along with other sensor information such as slide and spindle motor power and slide velocities. It is critical that there be excellent synchronization between program models and real time measurements.
3) It must have the ability to obtain current feed rate in real time as well as real time changes in the process, such as tool no., tool wear, M code, G code etc.
4) Application programs must be able to run on the PC while the NC machine is running, to pass sensor and position information to the programs model in a timely fashion.

B. Hardware Components

A schematic of the hardware components is shown in Fig 1.

- **CNC Machine**: NCU, the central processing unit of the 840D controller. It contains the NC-CPU and the PLC-CPU. It executes the NC program and maintains communication with the peripherals via numerous interfaces like MPI bus, Profibus DP I/O
- **PC Computer**: Pentium III 700Mhz or higher, 256 Mb RAM, Ethernet connection, MPI board (for online testing) One advantage of using the SIEMENS Open-CNC is that it is easy and relatively inexpensive to upgrade standard computer components with faster processing and more memory.
- **Data Acquisition Board**: Siemens makes PLC S7300 supports complex applications with greater number of I/O points with modular and expandable capabilities.
- **Spindle Sensor**: Spindle is equipped with Accelerometer (Vibration or external Shock monitoring system) [15]. This sensor provides data logging signal to the BlackBox Application running on PC Computer.

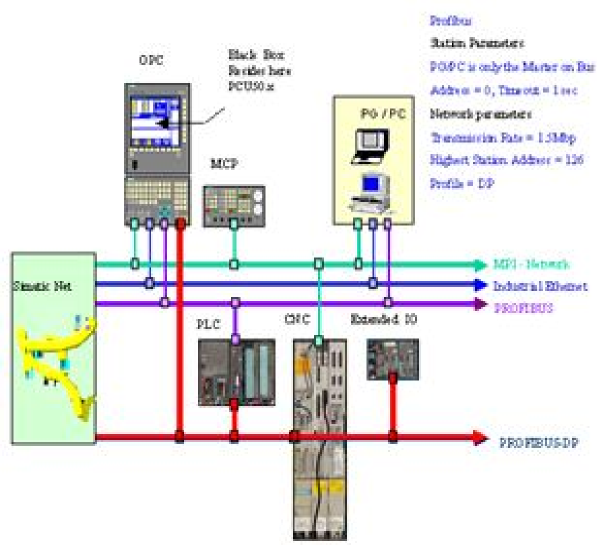

Figure 1. BlackBox linked with peripherals via Simatic Net

C. Software Components

A schematic of the software components is shown in Fig 2.

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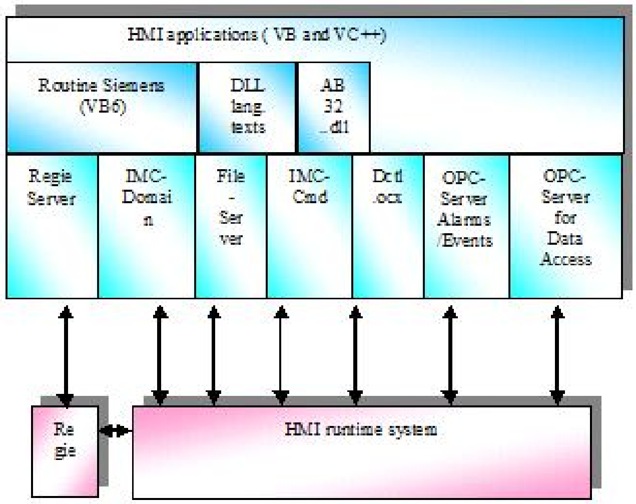

Figure 2. BlackBox linked with peripherals via Simatic Net

1)**Operating System**: Windows XP. It takes very few percentage of the CPU capability of the PC to control the CNC, leaving plenty of excess capability to run our applications.

2)Open Architecture Control Software: SIEMENS OpenCNC[16]. A key ingredient to this is the use of shared memory where both the SIEMENS controller and our application can simultaneously access vital information like the current G-code line number, axes position, velocity and spindle speed[17].

3)Real-Time Extension: The Windows operating system is not specifically designed for real-time operation so it requires some care in using it for CNC control. Reliability and safety are paramount concerns. A real-time command structure is required so that the motion control always receives the highest priority. The communication between applications and NC/PLC is carried out via the OPC or Sinumerik-COM interfaces. Communication with NCK shows restricted real time behavior.

4) **Software Development Environment**: Microsoft Visual Basic and Visual C++ 6.0. All of our application software is written in C++ providing speed, flexibility and portability.

IV. System implementation

A. Basic machine tool elements:

The functions of the CNC control are split up in five components

1) Human Machine Interface (HMI)
2) Programmable Logic Controller (PLC)
3) Numeric Control Kernel (NCK)
4) Drive control (SIMODRIVE devices)
5) Communication between the areas and with external components

There are many players in these fields, mainly Siemens, Fanuc, Allen Bradley, Hitachi, Mitsubishi are the major once. In order to realize this unique concept we have used Siemens Control System. Here are the few details.

- Human Machine Interface (HMI advance with PCU50.3)
- Programmable Logic Controller (S7-300 PLC)
- Numeric Control Kernel (840D/810D CNC)
- Drive control (SIMODRIVE devices, 611U drives)
- CPU – PCU50.3 or PCU50 with HMI Advance software installed

B. Application Concept

This application monitor [18] Numeric Controller, Drive control, Programmable Controller, Operator controls Panel and Machine Control Panel as Clint Server Model for it database in a cyclic manner illustrated in Fig 3 and Fig 4.

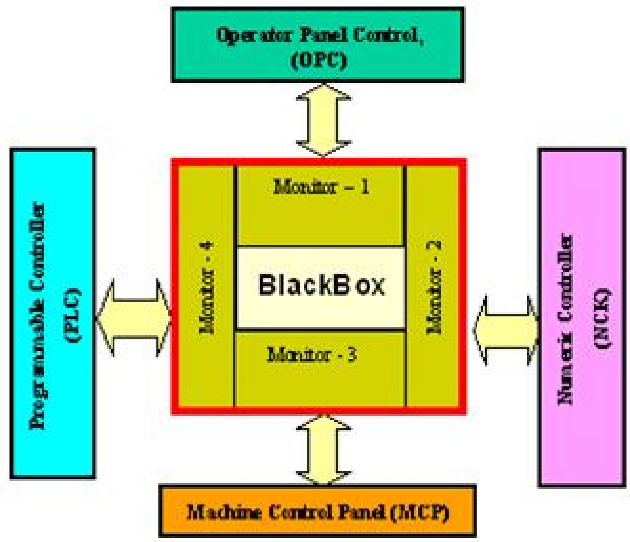

Figure 3. BlackBox interact with different units of Machine Tool

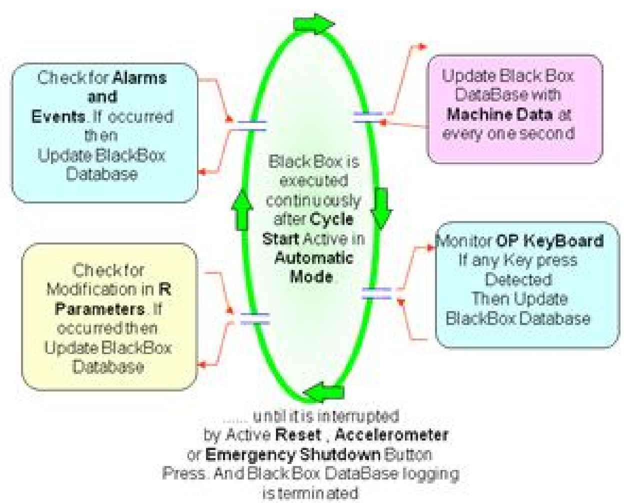

Figure 4. Flow Chart of BlackBox Application

Alls these data's will be stored into password protected Data Base at the time of Machine crash and can access only by Machine Tool Manufacturer via Web Page or Tele Service illustrated in Fig 5.

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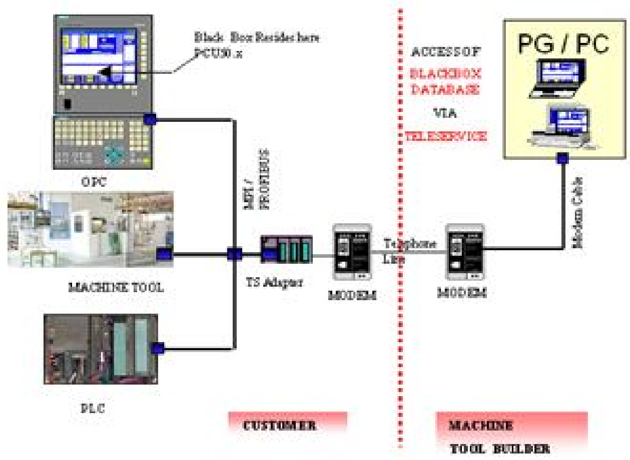

Figure 5. Remotely Retrieval of Black Box database

This complete Application developed in VB [19] platform. And its Data Management is build around Microsoft excess [20]. Event of crash is very essential in this application. Therefore, a dedicated sensor 'Accelerometer' is mounted on spindle to trigger the event of crash to BlackBox via PLC as shown in Fig 6.

C. Important Features.

- Scans and stores machine status after every 1-second.
- Up to last 5 min Machine data can be recovered just before breakdown
- Up to 10 crash data files can be recovered from machine
- Crash data can be recovered remotely via Internet/ Ethernet, no need to be present at the customer place.
- Machine Breakdown reason can be known remotely.
- File is password protected
- Each Machine data is time stamped.

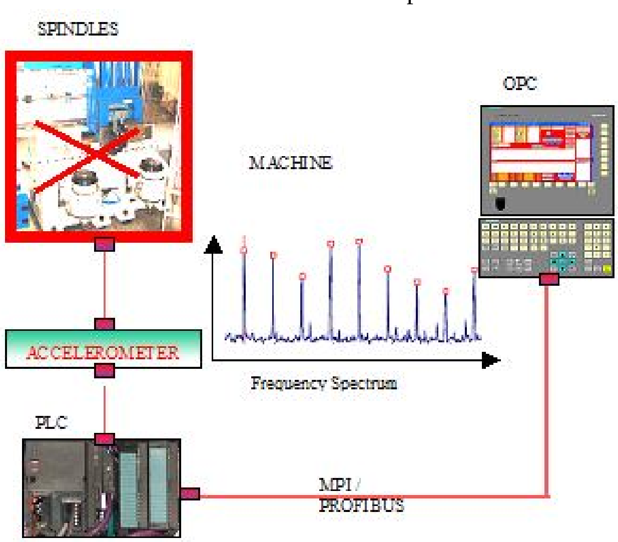

Figure 6. Event on accelerometer initiate the data logging

D. How to achieve?

By monitoring

- OPC key Pad, MCP, R parameters, Main and Sub programs.
- Number of Tools, tool parameters, offsets and tool magazine
- Spindle and Axis Overrides.
- Important NC and PLC data
- Events, Alarms and PLC messages.
- Status of all I/O's of PLC, Geometrical position as well as Rotational angle of all axis
- G, M parameters in use and operating mode AUTO/ MDI/JOG of Tool machine.

E. Application Results

BlackBox application source code developed around Visual Basic and Microsoft Access to capture data from NC, PLC and HMI controllers and write it on database file, as shown in Fig. 7 and Fig. 8 respectively at the moment of machine crash.

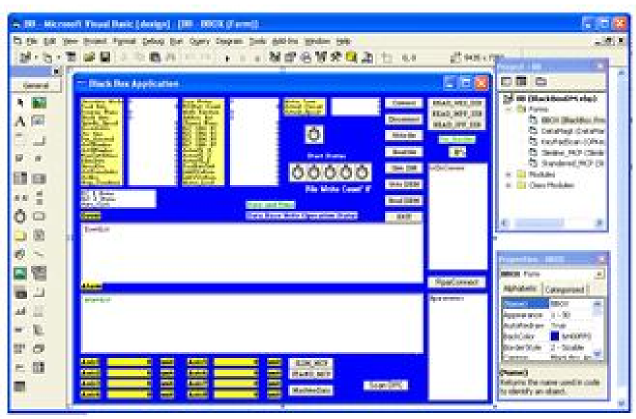

Figure 7. VB program

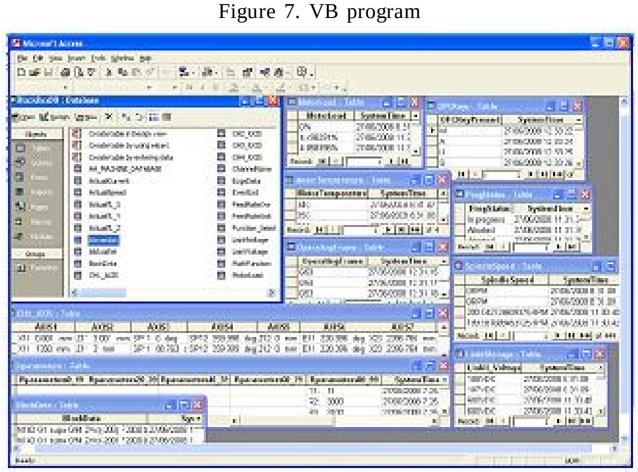

Figure 8. Machine crashed data file

F. Scope of improvements and future work

Database file of crashed machine is to be read thoroughly by the person to understand the cause of Machine Breakdown. Therefore, error in reading file and interpolating the cause of failure may be the bottom neck here and also the whole process is very much time consuming. So, there is always a possibility to build another application that will read and analyses the database file and suggest the possible cause of failure and also simulate the cause of machine breakdown.

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Conclusion

The use of open architecture CNC is considered of great importance since it is a promising technology that acts in the area of industrial automation, allowing the integration of the equipment, a friendlier interface in the configuration, machine tool Communication and modernization. This new black box application for Machine Tool Industry is successfully intergraded and tested with Siemens Open architecture CNC.

Appendix A

OAC	Open architecture control
CVR	Cockpit voice recorder
FDR	Aircraft's flight data recorder
CSMU	Crash-survivable memory unit
SDM	**Sensing and diagnostic module**
MPI	Multipoint interface
OPC	Operator panel control
MDI	Machine data Input

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Biographies

Atul Gupta received the B.E. degree in electronics and telecom engineering from Army Institute of Technology, affiliated to Pune University, MH, India, in 2002, and the M..Tech. degree in instrumentation from School Of Instrumentation, affiliated to DAVV University, Indore, MP, India. From 2004 to 2007, he was with the Research Division, TVS Electronics, Bangalore, India, where he was working on development of On-Line uninterruptible power system, sine wave inverters, and low-power dc–dc converters. He also worked at Emerson Network Power as Champion R&D at head office at thane, India. Since Sept 2007, he has been with the Engineering Design Center, Carraro Technologies, Pune, India, working on grid connected advance solar inverter design. His research interest includes Industrial Automation, Power Conditioning, Solar Energy, Hybrid Energy; Grid Interconnection of Renewable Energy sources.

Venu Uppuluri Srinivasa, holds Master's degree in Mechanical from Osmania University, Hyderabad, A.P, India. He also holds Master's degree in management & Post graduate diploma in Financial Management discipline. Has over 20 years of experience as an IT / ITes Technologist with both established public companies and Venture funded startups. Held senior executive roles in product marketing, strategy, product development and business development. Currently working as General Manager and Head for Carraro Technologies India Limited (an Italian Company) since 6 years representing Board as an authorized signatory. Also signed as board of director for Santerno India Private Limited. Served in the capacity of Engineering Director for Emerson Electric Co. (USA), Group Manager for Tecumseh Products India Limited

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